AIRFRAME ICING

As we joined the ranks of commercial pilots, we were introduced to airplanes that are certified for "flight into icing conditions." For many of us, that has been the entry to innocent ignorance, or what I call flying "Fat, dumb, and happy." I know that I – and perhaps most of us – have escaped danger unscathed without knowing we were exposed.

Part 25 Certification

What does Part 25 Appendix C certification assure? Is it a 100% guarantee of the ability to continue in icing conditions? No! Depending on temperature and Liquid Water Content, an airplane certified for flight into icing conditions may only be able to deal with ice for as little as 17 ½ nm. in "Continuous Icing" –in stratus clouds, or 3 ½ nm in "Intermittent" –ice in cumulous type clouds. So much for slogging along for an hour in ice at 10,000 to avoid even greater headwinds at 14,000. I, and others like me, have been lucky. Part 25 certification standards protect for droplets as large as 50 microns Mean Volumetric Diameter (MVD) –the size of a sharp point on a pencil. In other words, these are tiny droplets that we are hardly able to see that could cause significant ice on an aircraft.. Although modern aircraft enjoy much better performance enabling faster climbs through icing conditions, we should realize that the certification standards could lead to unwarranted complacency about performance.

Anything larger than 100 - 150 microns – existing at temperatures of 0° C. or less – is called SLD (Supercooled Large Droplet). By the time you can see a droplet – like drizzle – you can be sure that it is significantly larger than 50 microns. NASA has found that when droplets get to 175 microns, because they have the energy required to penetrate the boundary layer and strike aft of the protected areas, there is almost 100% collection efficiency. . That is, if there is SLD of 175 microns or larger, we can anticipate severe icing if we stay in those conditions.

Furthermore, we had operated under the common misconception that if we blew the boots too soon, we would build a bridge to be followed by certain death as the airplane plummeted to the ground with an unbreakable sheet of ice out in front of the airfoil. Well, Virginia, there may be a Santa, but there is no bridging. NASA has been trying to build a "bridge" for more than 10 years, and they could not produce one on an airplane or in a tunnel. If you see any ice, turn the boots on "continuous." (By the way, there is an AD for airplanes with boots to do just that.) I know that we may see a nice clean boot if we wait for a solid half inch or more, but the scraps left behind from "early" boot activation will be insignificant in cruise flight. Nonetheless, small amounts of ice may be a factor as one nears stall speed. Furthermore, that tail that we cannot see will probably accumulate sooner and more efficiently than the wing. If you see ice on the wiper, please, turn on the boots: the tail you save may be your own! If you are using heat, it should have been on a while ago. Heated wings have a protected area similar to a boot, but the heat actually evaporates the droplets on contact. If the ice only melts, the water may refreeze aft of the protected area – not a good thing. Late application of heat can cause runback, where the water refreezes aft of the protected area. Similarly, nacelle heat needs to be on at 10°C and less when in visible moisture. Remember that expansion within the nacelle inlet can cause a temperature decrease resulting in ice formation while none is present on the airframe. This sort of ice can cause serious disruptions in engine airflow.

Up until recently, the government required airlines only to publish Holdover times, and procedures for deicing/anti-icing on the ground. At least one fatal accident has prompted the government to tell carriers to address severe icing – *in flight*, which is where we can get into serious trouble. Severe icing is a subjective observation: if there is more ice than the system can handle, or if ice is accreting aft of the protected surfaces, it is severe. *No airplane is certified for flight in severe icing.*

<u>Severe Icing is an Experience.</u>

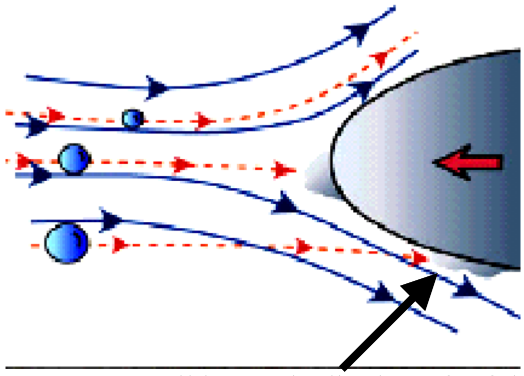
Severe icing does not exist in and of itself. It is a subjective observation. A C-172 with ¼" of rime is experiencing severe icing. A Saab is experiencing severe icing when it begins to accrete aft of the boots, or if it simply cannot keep up with the accretion. If a B-757 is experiencing moderate icing, one should expect a more serious accumulation in aircraft with less climb performance and different ice protection systems. In other words, with valid information, we can anticipate conditions that may cause severe icing. If we do, there are ways to avoid the *experience.* The most important tool for making plans – in the absence of a crystal ball – is PIREPS. Without PIREPS we can make an educated guess sometimes, or just hope for the best.

Holdover Times Anticipated for SAE Type IV Fluid 100% Mixture

Approximate Holdover Times under Various Weather Conditions
(hours: minutes)

OAT	**Freezing Drizzle	Light Freezing Rain
Above 0°	0:40 – 1:10	0:25 – 0:40
0 to -3	0:40 – 1:10	0:25 – 0:40
Below -3 to -14	0:20 – 0:45*	0:10 – 0:25*

A look at the Holdover table for Type IV fluid shows that we should be protected at -3°C. from 25 to 40 minutes in light Freezing Rain. Just to the left, we can see 40 minutes to an hour and 10 minutes in Freezing Drizzle. As long as we are on the ground, we can anticipate that protection, but almost all the fluid will be left on the runway as we takeoff. Should we anticipate conditions that produce severe icing?   Well, light Freezing Rain droplets are larger than 200 microns (remember the 175 mentioned above). If we should *fly* in light Freezing Rain for enough time, we can be sure to accrete aft of the protected surfaces.



Note SLD striking and adhering aft of the boot.

The much longer Holdover times for Freezing Drizzle would lead one to believe that there is much less risk in flying in Freezing Drizzle. Once again, is Freezing Drizzle SLD? The first clue is we can see the droplets. Freezing Drizzle droplets run 150 – 200 microns. Note that the average size is 175, which will impinge on the surface aft of our protected areas. If we fly in those conditions, we *will* experience severe icing.

Freezing Drizzle areas have another interesting characteristic: they have enormous Liquid Water Content (LWC). In fact, NASA has found that a cubic meter of Freezing Drizzle contains *2 to 3 times* the mass of water found in a cubic meter of Freezing Rain! Therefore- with 100% collection efficiency thanks to the size of the droplets - when we fly through Freezing Drizzle, we should expect a great deal more ice to accumulate on the airplane than we would in Freezing Rain. As long as we stay on the ground, the Freezing Drizzle will not wash away Type IV fluid as quickly as Light Freezing Rain will, but don't let that lead you into a false sense of security regarding *flight* in those conditions.

So, when is it safe to takeoff in conditions of Light Freezing Rain or Freezing Drizzle? If we know that we will be out of the SLD conditions within a thousand feet or so, might we be comfortable? How do we know? Obviously adiabatic rate will not help: there is probably an inversion. As with other icing situations, the best information is from PIREPS. If there is Light Freezing Rain on the surface, there will usually be an inversion less than 2,500 AGL. It may be as low as a few hundred feet, in which case we would not *experience* the severe icing since we would not be in the conditions long enough to accrete significant amounts aft of the protected areas (unless you plan to cruise at two hundred feet!).

We all know that we must not fly in severe icing conditions. If we can fly through the conditions that would produce severe icing quickly enough, we will not experience the severe icing. Most situations that have the potential to cause severe icing are relatively small in terms of geography, thickness, and time. The conditions are seldom more than 3,000' thick: therefore, the best escape is normally a change in altitude. This can be critically important during holding or extensive vectoring. If you find yourself in severe icing conditions during such events, get a new altitude *without delay.* ATC has become quite sensitive to these situations, and you can expect their immediate cooperation. If you stay in severe icing conditions, you are inviting an emergency, the consequences of which you may not be able to control. A certain airline's pilots have numerous stories of severe icing encounters that have resulted in control problems. Fortunately, none has resulted in an accident. While we are on the subject, airplanes with unboosted controls should be flown manually – at least periodically – when in moderate ice. If you leave the airplane on autopilot, you will not feel control feedback that may warn you of impending problems.

We all need to be making more PIREPS. Without PIREPS, we do not know if there is ice, or if there is *negative* icing! Remember, if no one says anything, there is no information for others to make decisions. If you are experiencing ice, report the temp., type, and altitude. If you do not accrete ice in conditions where one might expect ice, report negative icing.

Arrivals.

The requirements to study Holdover times and the obligatory crew actions take no account of arrivals. What do you think about arriving in Light Freezing Rain or Freezing Drizzle? As with departure, the threat is measured by the time you may spend in the SLD conditions. If the inversion is a few hundred AGL, you may not accrete a significant amount prior to landing. On the other hand, if you find yourself in the SLD at - or prior to - the OM, the nature of the situation is different indeed. One pilot described entering SLD at about 1,000 AGL (well inside the FAF), and on post-flight inspection, he found the lower surface of the wing and his side windows covered with ice! If he had needed to go around, the success of the maneuver would have been doubtful. Another crew described entering a cloud during a procedure turn. In about 30 seconds, the aircraft suffered such an accumulation that the stall shaker activated, and they finally recovered in VFR about 1200 AGL!

What can we do to determine if we are accreting aft of the protected areas? Generally, the windshield wipers are the first to accrete because of their small leading edge. If there is an unusually large accretion, that is cause for suspicion – if not concern. If there is ice on the side windows (especially the aft portion), chances are excellent there is accretion on other unprotected areas. Therefore, one might consider turning OFF the Side Window heat in order to get a better idea of the icing conditions that we cannot see – but may be accumulating - aft of the protected areas.

If you are faced with a severe accumulation on short final, anything other than a landing will be an adventure not-to–be-enjoyed. As you slow down, angle of attack increases even if the wing is clean. Now add ice to the equation, and the wing sees an even higher angle of attack.. The margin above stall – if any - has decreased to an unknown point. We have distorted the airfoil, changed the critical angle of attack, and if confronted with a go-around situation, we will be in uncharted territory. The chances of trouble are great and success slim. It may be necessary to exercise emergency authority and land on an occupied runway, or a vacant taxiway – alternatives preferable to stalls close to the ground. Last year, a turboprop crew had such a sudden accumulation, and they declared an emergency. They warned the tower that they would not be able to go around and to plan accordingly: Good thinking.

Several people have asked about practicing ice-encumbered stalls in the simulator. Simulators accurately reproduce events that have been charted in the airplane with sophisticated sensors. The simulators we use simply add gross weight to the equation. The NASA research has shown that distortion of the airfoil is the most significant concern in icing, and the weight increase is of comparatively little consequence. There is no program that demonstrates the violent rolling motions that a few have experienced in some aircraft, and there are no simulators that emulate tail stalls.

Is there any good news?

Yes. As a general rule, airframe icing is experienced in about 40% of encounters where we have visible moisture at temperatures below freezing. As we get into temperatures of -20° C. and less, the chances decrease to about 14%, and they decrease to 0% at -40 °. There must be at least *some liquid* water before any ice accretion is possible. If there is only snow, icing is unlikely since the cloud is completely glaciated – there is no liquid water. (The colder the air mass the less likely is airframe icing.) Severe icing conditions seldom continue laterally more than 50 nm, nor more than 3,000' vertically. The conditions are usually short-lived too. If conditions are dangerous for landing at your destination, they may not last long, and you can probably find a safe alternate within 100 miles.

At the risk of being repetitive, please note that this information makes PIREPS that much more important. Dispatch and ATC (not to mention pilots!) cannot know of actual changes without our reports. Recently, an flight was ready to divert because of reports of severe icing by a 737 departing a field. Shortly, ATC passed along a PIREP from an arriving Dash-8 – on the opposite side of the airport. The Dash had experienced light ice on the arrival a few miles and minutes behind the Boeing. The flight was able to make the planned arrival thanks to timely PIREPS.

Acknowledgment
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